

MISSION OPERATIONS AND DATA SYSTEMS DIRECTORATE

Landsat-7 Image Assessment System (IAS) Element Specification

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National Aeronautics and
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Preface

This specification is intended to document the National Aeronautics and Space Administration (NASA) level 3 requirements of the Landsat 7 Image Assessment System (IAS) to be used by the developing organizations. These requirements were originally derived from the Landsat 7 System Specification.

The traceability matrices in section 5 have used the Landsat 7 Detailed Mission Requirements (DMR) baseline, dated March 1996.

This specification is controlled by the IAS Project within the ETM+ Processing Facility (EPF) of Code 514 and may be changed by Document Change Notice (DCN) and/or revision procedures. Comments and questions regarding this specification should be directed to

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Abstract

This specification presents the National Aeronautics and Space Administration (NASA) Level 3 interface, functional, performance, and operational requirements for the Landsat 7 Image Assessment System (IAS). This document will be baselined by the IAS Project for developing and implementing the system. Other documents will contain the further decomposition and allocation of these requirements to system design elements.

Also included in this specification are a requirements verification matrix and traceability matrices tracing the IAS requirements to the Landsat 7 detailed mission requirements (DMR).

Keywords: *Image Assessment System (IAS), requirements, specification*

List of TBDs/TBRs

Section	Description
3.2.2.4.7	Evaluation of radiometric response with respect to linearity (TBD)
3.2.3.20	On-line storage capacity; 100 GB (TBR) for image data
3.2.4.5	Shift requirement for IOC + 48 days (TBR)
3.2.4.6	Shift requirement for post-IOC (TBR)
Table 3.2.4-2	Frequency of assessments and evaluation activities (TBR)
3.2.4.11	Operational availability of .85 (TBR)
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Section 1. Scope

This document contains the element-level functional, performance, operational, and interface requirements for the Image Assessment System (IAS). These requirements are traceable to the Landsat 7 system specification (Applicable Document 1) and the Landsat 7 detailed mission requirements (DMR), and they were derived by the Landsat 7 Project Science Office in conjunction with the interagency Landsat Science Quality Assurance Team (LSQAT). Section 4 consists of the requirements verification matrix, which lists all 3.2 requirements and their method of verification. Section 5 includes traceability matrices with the Landsat 7 DMR.

Section 2. Applicable Documents

1. National Aeronautics and Space Administration (NASA), Goddard Space Flight Center (GSFC), 430-L-0002-H, *Earth Science Mission Operations Landsat 7 System Specification*
2. Martin Marietta Astro Space, *Landsat-7 Image Assessment System Operations Concept*, September 1994
3. Martin Marietta Astro Space, CDRL #A058, 23007610A, *Landsat-7 Program Coordinate System Standard, Rev. B*, December 1994
4. Martin Marietta Astro Space, CDRL No. A104, *Space Segment Calibration Plan*, August 1994
5. Computer Sciences Corporation, *Landsat-7 MOC to IAS Interface Control Document*
6. NASA, GSFC, 514-1 ICD/0195, *Interface Control Document Between the IAS and the LPS*
7. Hughes Information Technology System, 209-CD-013-002, *Interface Control Document Between ECS and the Landsat 7 System*
8. AlliedSignal Technical Services Corporation, *Landsat 7 Detailed Mission Requirements*, March 1996

Section 3. Requirements

3.1 Element Definition

The IAS is an element of the Landsat 7 Ground Data Handling Segment. It is responsible for off-line assessment of image quality to ensure compliance with the radiometric and geometric requirements of the spacecraft and the Enhanced Thematic Mapper Plus (ETM+) sensor throughout the life of the mission.

In addition to its assessment functions, the IAS is responsible for the radiometric and geometric calibration of the Landsat 7 satellite and ETM+. Initial calibration data, in addition to sensor characteristics and models, are received prelaunch from the ETM+ contractor [the Santa Barbara Research Center (SBRS)] and the Space Segment Satellite (LMMS). The IAS periodically performs radiometric and geometric calibration and passes calibration coefficient updates directly to the Earth Resources Observation System (EROS) Data Center (EDC) Distributed Active Archive Center (DAAC) and to international ground stations (IGSs) through the Mission Operations Center (MOC). Anomalies are reported to the MOC, Landsat Processing System (LPS), EDC DAAC, and Mission Management Office (MMO) as needed.

The IAS obtains Level 0R data and products from the EDC DAAC. These data include ancillary information such as metadata. The IAS assesses image data in raw form and by processing the data to Level 1R and 1G for assessment as Level 1 products. Image data are assessed with respect to their geometric and radiometric qualities on an individual sample and long-term trending basis. Data quality assessments, reports, and improved processing instructions are sent to the EDC DAAC, LPS, MOC, and MMO.

3.2 Image Assessment System Requirements

3.2.1 Interface Requirements

3.2.1.1 EDC DAAC

3.2.1.1.1 The IAS shall interface with the EDC DAAC for purposes of searching for and ordering of data from the Landsat 7 archive.

3.2.1.1.2 The IAS shall receive Level 0R data, Level 0R products, and associated ancillary data from the EDC DAAC.

3.2.1.1.3 The IAS shall interface with the EDC DAAC to coordinate the transfer of calibration parameter files and IAS-generated reports.

3.2.1.1.4 The IAS shall send calibration parameter files and IAS-generated reports to the EDC DAAC.

3.2.1.2 Landsat 7 Processing System

3.2.1.2.1 The IAS shall interface with the LPS to coordinate the transfer of calibration parameter files and reprocessing requests.

3.2.1.2.2 The IAS shall send reprocessing requests to the LPS.

3.2.1.2.3 The IAS shall receive disposition of reprocessing requests from the LPS.

3.2.1.2.4 The IAS shall send calibration parameter files to the LPS.

3.2.1.3 Mission Operations Center

3.2.1.3.1 The IAS shall send requests to the MOC for the operational acquisition of partial-aperture calibration data, full-aperture calibration data, and surface image data of radiometric and geometric calibration ground sites.

3.2.1.3.2 The IAS shall coordinate with the MOC for the acquisition of ETM+ imagery required for calibration and image assessment, for the transfer of calibration parameter files, and for the transfer of problem reports.

3.2.1.3.3 The IAS shall send requests to the MOC for concentrated definitive ephemeris.

3.2.1.3.4 The IAS shall send problem reports to the MOC.

3.2.1.3.5 The IAS shall send calibration parameter files to the MOC.

3.2.1.3.6 The IAS shall be capable of receiving telemetry trend reports, spacecraft status reports, and event schedules from the MOC.

3.2.1.3.7 The IAS shall be capable of receiving Flight Dynamics Facility (FDF)-generated, definitive ephemeris from the MOC.

3.2.1.4 Mission Management Office

3.2.1.4.1 The IAS shall send problem reports and summary reports to the MMO.

3.2.2 Functional Requirements

3.2.2.1 Radiometric Calibration

3.2.2.1.1 The IAS shall be able to use data from the internal calibrator in the calibration of the radiometric response of each ETM+ detector.

3.2.2.1.2 The IAS shall be able to calibrate the radiometric response of each ETM+ detector, except band 6, using data from the partial-aperture solar calibrator (PASC).

3.2.2.1.3 The IAS shall be able to calibrate the radiometric response of each ETM+ detector, except band 6, using data from the full-aperture solar calibrator (FASC).

3.2.2.1.4 The IAS shall be able to calibrate the radiometric response of each ETM+ detector given Level 0R data of a ground calibration site and corresponding at-aperture spectral radiance values.

3.2.2.1.5 The IAS shall be able to calibrate the radiometric response of each ETM+ detector using Level 0R data from preship and prelaunch calibration sources and auxiliary calibration source data.

3.2.2.1.6 The IAS shall have the capability of assessing the short-term and long-term stability of the onboard calibration sources, which include the FASC, the PASC, and the internal calibrators.

3.2.2.1.7 The IAS shall be able to integrate the results of the various calibration processes into an optimal estimate of radiometric calibration of each detector (except band 6) and provide new calibration parameters.

3.2.2.1.8 The IAS shall be capable of generating radiometric calibration updates for the calibration parameter file.

3.2.2.1.9 The IAS shall be able to transfer the calibration of each detector to the internal calibrator.

3.2.2.2 Geometric Calibration

3.2.2.2.1 The IAS shall be capable of determining the misalignment between the satellite navigational base reference and the ETM+ payload line-of-sight (LOS).

3.2.2.2.2 The IAS shall be capable of determining band-to-band registration parameters.

3.2.2.2.3 The IAS shall be capable of characterizing and updating along and across scan parameters (i.e., scan mirror profiles, scan-line corrector mirror profile, detector offsets, detector delays).

3.2.2.2.4 The IAS shall be capable of generating geometric calibration updates for the calibration parameter file.

3.2.2.3 Level 1 Processing

3.2.2.3.1 The IAS shall be capable of processing payload correction data (PCD) data to correct spacecraft time, generate a sensor pointing model (attitude and jitter), and calculate spacecraft position and velocity (ephemeris).

3.2.2.3.2 The IAS shall be capable of processing ETM+ Level 0R products to produce radiometrically corrected Level 1R image data.

3.2.2.3.3 The IAS shall be capable of creating systematically corrected ETM+ Level 1G imagery from Level 0R products.

3.2.2.3.4 The IAS shall be capable of creating precision corrected ETM+ Level 1G imagery from Level 0R products and ground control points (GCPs).

3.2.2.3.5 The IAS shall be capable of creating terrain corrected ETM+ Level 1G imagery from Level 0R products, GCPs, and elevation data.

3.2.2.3.6 The IAS shall be capable of performing image-to-image registration.

3.2.2.3.7 The IAS shall be capable of incorporating IAS-generated calibration coefficient updates to generate Level 1 data.

3.2.2.3.8 The IAS shall support nearest neighbor, cubic convolution, and modulation transfer function (MTF) compensation resampling.

3.2.2.3.9 The IAS shall have the capability to produce a 1G product with a grid cell size that is variable from 15 to 60 meters, in increments of 1 millimeter (mm).

3.2.2.3.10 The IAS shall have the capability to map project 1G using the Space Oblique Mercator, Universal Transverse Mercator, Lambert Conformal Conic, Transverse Mercator, Oblique Mercator, and Polyconic coordinate reference systems.

3.2.2.3.11 The IAS shall have the capability to create a 1G image oriented to nominal path or north-up.

3.2.2.3.12 The IAS shall be capable of processing Mirror Scan Correction Data (MSCD) to generate scan mirror and scan line corrector mirror models.

3.2.2.3.13 The IAS shall be capable of compensating for inoperable and saturated detectors during Level 1R and 1G processing.

3.2.2.3.14 The IAS shall be capable of compensating for the image artifacts of striping, banding, coherent noise, memory effect, and scan correlated shift in Level 1R and 1G processing.

3.2.2.3.15 The IAS shall be capable of processing to Level 1R and 1G both ascending and descending pass ETM+ Level 0R data.

3.2.2.3.16 Deleted

3.2.2.4 Performance Evaluation

3.2.2.4.1 The IAS shall evaluate the on-orbit operability of ETM+ detectors.

3.2.2.4.2 The IAS shall be able to evaluate the absolute radiometric accuracy of ETM+ Level 0R, 1R, and 1G data.

3.2.2.4.3 The IAS shall be able to assess the identified ETM+ radiometric image artifacts of striping; banding; random, correlated, and coherent noise; memory effect; and scan-correlated shift.

3.2.2.4.4 The IAS shall be able to evaluate the MTF of each ETM+ detector.

3.2.2.4.5 The IAS shall be able to evaluate the signal-to-noise ratio (SNR) of each ETM+ detector, using prelaunch and on-orbit image data.

3.2.2.4.6 The IAS shall be capable of evaluating the on-orbit radiometric response of each ETM+ detector with respect to dynamic range.

3.2.2.4.7 The IAS shall be capable of evaluating the on-orbit radiometric response of each ETM+ detector, excluding band 6, with respect to linearity (TBD).

3.2.2.4.8 The IAS shall be able to evaluate the geodetic accuracy of ETM+ Level 1G image data.

3.2.2.4.9 The IAS shall be able to evaluate the internal geometric accuracy of ETM+ Level 1G image data.

3.2.2.4.10 The IAS shall be able to evaluate the band-to-band registration accuracy of ETM+ imagery.

3.2.2.4.11 The IAS shall be able to evaluate the image-to-image registration accuracy of ETM+ data.

3.2.2.4.12 The IAS shall be able to evaluate the quality of Level 0R products. Quality checks will include but not be limited to those listed in Table 3.2.2.4-1.

Table 3.2.2.4-1. L0R Product Quality Checks

Imagery	Calibration Parameter File
Visual check	Applicability date consistent with imagery
Process to 1R/1G	Consistency with IAS database
Payload Correction Data	Metadata
Range check all but housekeeping	ACCA scores (visual check)
Validated in 1G model	Scene coordinates
	File name consistency
	WRS scene parameters correctness (Sun angles, scene center lat/long, asc/desc flag, etc.).
Mirror Scan Correction Data	Calibration Pulse/Shutter
Validated in 1G model	Calibration outliers
Scan direction consistency	Shutter mean
FHSERR/SHSERR consistency	Shutter standard deviation
Counted line length consistency	Shutter outliers
Dropped line locations	

3.2.2.4.13 The IAS shall be capable of performing a trend analysis over any desired time interval for each selected evaluation activity.

3.2.2.4.14 Moved to 3.2.4.14.

3.2.2.4.15 The IAS shall provide the capability to visually inspect image data.

3.2.2.4.16 The IAS shall provide a capability that allows an image analyst to monitor assessment processes and results.

3.2.2.4.17 The IAS shall have the capability to review output data, including but not limited to calibration reports and updates.

3.2.2.5 Incorporation of New Algorithms

3.2.2.5.1 The IAS shall have the capability to acquire, develop, test, and add new algorithms and software to improve the radiometric and geometric properties of ETM+ data and their assessment without impacting IAS operations.

3.2.2.5.2 The IAS shall support the development of algorithms to remove image artifacts and detector outages from Level 1R and 1G data without impacting normal IAS operations.

3.2.2.5.3 The IAS shall have the capability to incorporate new algorithms into the operational system without impacting normal IAS operations.

3.2.2.5.4 The IAS shall maintain configuration control of all algorithms, databases, software, and hardware used in operations.

3.2.2.6 Process Control and Manage Data

3.2.2.6.1 The IAS shall provide the capability to select the processing to be applied to data sets.

3.2.2.6.2 The IAS shall be capable of archiving all software and databases used in operations.

3.2.2.6.3 The IAS shall be capable of storing selected data, parameters, ancillary data, reports, and documents.

3.2.2.6.4 The IAS shall have the ability to monitor and control processes.

3.2.2.6.5 The IAS shall be capable of storing selected GCPs and GCP chips.

3.2.2.6.6 The IAS shall be capable of storing selected digital elevation models (DEMs).

3.2.2.6.7 Deleted

3.2.2.6.8 The IAS shall be capable of storing solar spectral and broadband radiance data.

3.2.2.6.9 The IAS shall have the capability to write outputs to tape.

3.2.2.6.10 The IAS shall have the capability to generate hardcopy outputs.

3.2.2.6.11 The IAS shall archive selected prelaunch data, including but not limited to sensor engineering, ETM+ image data, alignment matrices, calibration measurements, mirror scan profiles, FASC bi-directional reflectance distribution function (BRDF), relative spectral subsystem response on a detector-by-detector basis, and required characterization data for performing in-flight calibrations.

3.2.2.6.12 The IAS shall allow the operator to select thresholds for results and errors reported by the IAS.

3.2.2.6.13 The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.

3.2.2.7 Reports and Summaries

3.2.2.7.1 The IAS shall generate calibration, data quality assessment, and problem reports.

3.2.2.7.2 The IAS shall be capable of generating metadata for all reports sent to the EDC DAAC Guide Server.

3.2.2.7.3 The IAS shall generate annual reports that document calibration coefficient and performance analysis trends.

3.2.2.7.4 The IAS shall generate reports of anomaly detection analyses as they are concluded.

3.2.2.7.5 The IAS shall generate processing summaries after each IAS activity.

3.2.3 Performance Requirements

Accuracy

3.2.3.1 The IAS shall be capable of calibrating the radiometric response (absolute spectral radiance) of each operable ETM+ detector to an accuracy of 5 percent, 1 sigma, providing all inputs are within specification.

3.2.3.2 The IAS shall be capable of calibrating the relative radiometric response such that the ratio of ETM+ equivalent at-aperture radiances between any combination of two spectral bands, excluding band 6, shall vary less than 2 percent, 1 sigma, over a 7-day period when exposed to a spectrally constant source.

3.2.3.3 The IAS shall contribute no greater than 0.7 percent uncertainty to absolute radiometric accuracy during the generation of Level 1R and 1G data.

3.2.3.4 The IAS shall be able to create systematic imagery to a geodetic accuracy of 250 meters, 1 sigma, providing all inputs are within specification. Performance applies to along-track and cross-track directions and is referenced to a nadir-viewing geometry.

3.2.3.5 The IAS shall contribute circular errors no greater than 1.8 meters, 1 sigma, in the production of systematically corrected ETM+ Level 1G imagery. This error is referenced to a nadir-viewing geometry and excludes the effect of terrain correction.

3.2.3.6 The IAS shall provide the capability to register pixels from a band to the corresponding pixels of the other bands in a common scene to an accuracy of 0.28 sensor guide star data (GSD), 0.9p, in along-track and cross-track directions, providing all inputs are within specification. The accuracy is relative to the largest sensor GSD of the registered bands.

3.2.3.7 The IAS shall contribute error no greater than 0.11 multispectral sensor GSD, 0.9p, along-track, and 0.24 multispectral sensor GSD, 0.9p, cross-track, in the assessment of band-to-band registration.

3.2.3.8 The IAS shall provide the capability to perform image-to-image registration to an accuracy of 0.4 multispectral sensor GSD, 0.9p, in the along-track and cross-track directions providing all inputs are within specification.

3.2.3.9 The IAS shall contribute circular errors no greater than 3.6 meters, 1 sigma, during image-to-image registration correction of ETM+ Level 1G data. Error is referenced to a nadir-viewing geometry and excludes the effect of terrain correction.

3.2.3.10 The IAS shall be capable of estimating the field angles to an accuracy of 0.18 arcsec, 1 sigma.

3.2.3.11 The IAS shall be capable of digitally correlating common features in separate bands of the same image or same bands of separate images to an accuracy of 0.1 pixel, 0.9p.

3.2.3.12 The IAS shall be capable of estimating the alignment of the ETM+ line-of-sight to the satellite navigation base reference to an accuracy of 24 arcsec, 1 sigma, in all axes.

Throughput

3.2.3.14 The IAS shall be capable of generating the equivalent of up to 10 ETM+ Level 1G systematically corrected scenes in a 24-hour day over the life of the mission. (**NOTE:** This requirement is meant to size the maximum capacity of the system.)

3.2.3.15 The IAS shall be capable of receiving and storing 10 ETM+ Level 0R scene products or equivalent per day of data from the EDC DAAC.

3.2.3.16 The IAS shall be capable of archiving test site image data (initial, intermediate, and final products), characterization data, calibration data, calibration parameter files, and reports, generated by the IAS, over the life of the mission.

3.2.3.17 The IAS shall generate monthly reports that document the quality of 0R data and 0R products retrieved from the EDC DAAC.

3.2.3.18 The IAS shall provide regular calibration and performance updates to the EDC DAAC and other interfaces quarterly.

3.2.3.19 The IAS shall provide an annual Landsat 7 image quality report.

3.2.3.20 The IAS shall have an on-line data storage capacity of 100 gigabytes (GB) (TBR) for image data.

3.2.3.21 The IAS shall be capable of storing 68 megabytes (MB) of GCP data (points, chips, metadata).

3.2.3.22 The IAS shall be capable of storing 20 GB of elevation data.

3.2.4 Operational Requirements

3.2.4.1 Deleted

3.2.4.2 The IAS shall support end-to-end testing at least 12 (TBR) months before launch.

3.2.4.3 The IAS shall be capable of supporting full operations at launch -6 months.

3.2.4.4 The IAS shall support mission operations for a minimum of 5 years following in-orbit checkout (IOC).

3.2.4.5 The IAS shall operate two shifts for 7 days a week during IOC plus 48 days (TBR).

3.2.4.6 The IAS shall be staffed during prime shift post-IOC plus 48 days (TBR).

3.2.4.7 The IAS shall ensure backup of all on-line data and operations software.

3.2.4.8 The IAS shall perform calibrations, assessments, and evaluations with frequencies specified in Tables 3.2.4-1 and 3.2.4-2.

Table 3.2.4-1. Frequency of Calibration Activities

Calibration Activity	Activity Frequency	Reporting Frequency
Sensor alignment calibration	Once during IOC and at no more than 90-day intervals	Quarterly
Band-to-band registration	Once during IOC and at no more than 90-day intervals	Quarterly

Detector delay calibration	Once during IOC and at no more than 90-day intervals	Quarterly
Radiometric calibration	Once during IOC and at no more than 90-day intervals	Quarterly

Table 3.2.4-2. Frequency of Assessment and Evaluation Activities (TBR)

Assessments	Assessment Frequency	Reporting Frequency
Detector operability	Once during IOC and at most each time FASC image collected	Quarterly
Radiometric accuracy	Once during IOC and at most on 90-day intervals	Quarterly
Streaking and banding	Once during IOC and at most on 90-day intervals	Quarterly
Correlated and coherent noise	Once during IOC and at most each time FASC image collected	Quarterly
MTF	Once during IOC and at most on 90-day intervals; needs MTF ground targets	Quarterly
SNR	Once during IOC and at most each time FASC image collected	Quarterly
Geodetic accuracy	At most on 90-day intervals	Quarterly
Geometric accuracy	At most on 90-day intervals	Quarterly
Band-to-band registration accuracy	At most on 90-day intervals	Quarterly
Image-to-image registration accuracy	At most on 90-day intervals	Quarterly
Image artifacts	At most on 90-day intervals	Quarterly
Evaluate	Evaluation Frequency	Reporting Frequency
LPS data quality	Every 30 days	Monthly and annually
Level 0R data and products	Daily	Monthly and annually
Level 1R data quality	Every 30 days	Quarterly and annually
PCD quality	Every 30 days	Monthly and annually
Selected trend analyses	Annually	Annually

3.2.4.9 The IAS shall have the capability to maintain and upgrade all operational software.

3.2.4.10 The IAS shall be capable of supporting training without impacting daily work loads.

3.2.4.11 The IAS shall provide an operational availability of 0.85 (TBR) or better for all processing functions.

3.2.4.12 The IAS shall support a mean-time-to-restore (MTTR) capability of 12 (TBR) hours or better.

3.2.4.13 The IAS shall be capable of retrieving cross-calibration data of other sensors from the EDC DAAC.

3.2.4.14 The IAS capability shall be used in performing anomaly assessment, resolution, and reporting.

Section 4. Verification

Verification Matrix for IAS 3.2 Element Specifications

I=Inspection A=Analysis D=Demonstration T=Test

3.2 REQS	3.2 REQUIREMENTS SUMMARY	I	A	D	T
3.2.1 Interface Requirements (EDC DAAC, LPS, MOC, MMO)					
3.2.1.1.1	The IAS shall interface with the EDC DAAC for purposes of searching for and ordering of data from the Landsat 7 archive.				x
3.2.1.1.2	The IAS shall receive Level 0R data and Level 0R products and associated ancillary data from the EDC DAAC.				x
3.2.1.1.3	The IAS shall interface with the EDC DAAC to coordinate the transfer of calibration parameter files and IAS-generated reports.			x	
3.2.1.1.4	The IAS shall send calibration parameter files and IAS-generated reports to the EDC DAAC.				x
3.2.1.2.1	The IAS shall interface with the LPS to coordinate the transfer of calibration parameter files and reprocessing requests.			x	
3.2.1.2.2	The IAS shall send reprocessing requests to the LPS.				x
3.2.1.2.3	The IAS shall receive disposition of reprocessing requests from the LPS.				x
3.2.1.2.4	The IAS shall send calibration parameter files to the LPS.				x
3.2.1.3.1	The IAS shall send requests to the MOC for the operational acquisition of partial-aperture calibration data, full-aperture calibration data, and surface image data of radiometric and geometric calibration ground sites.				x
3.2.1.3.2	The IAS shall coordinate with the MOC for the acquisition of ETM+ imagery required for calibration and image assessment, for transfer of calibration parameter files, and for transfer of problem reports.			x	
3.2.1.3.3	The IAS shall send requests to the MOC for concentrated definitive ephemeris.				x
3.2.1.3.4	The IAS shall send problem reports to the MOC.				x
3.2.1.3.5	The IAS shall send calibration parameter files to the MOC.				x
3.2.1.3.6	The IAS shall be capable of receiving trend reports, spacecraft status reports, and event schedules from the MOC.				x
3.2.1.3.7	The IAS shall be capable of receiving FDF-generated definitive ephemeris from the MOC.				x
3.2.1.4.1	The IAS shall send problem reports and summary reports to the MMO.			x	
3.2.2 Functional Requirements					
3.2.2.1 Radiometric Calibration					
3.2.2.1.1	The IAS shall be able to use data from the internal calibrator in the calibration of the radiometric response of each ETM+ detector.				x

3.2.2.1.2	The IAS shall be able to calibrate the radiometric response of each ETM+ detector, except band 6, using data from the PASC.		x		x
3.2.2.1.3	The IAS shall be able to calibrate the radiometric response of each ETM+ detector, except band 6, using data from the FASC.		x		
3.2.2.1.4	The IAS shall be able to calibrate the radiometric response of each ETM+ detector given Level 0R data of a ground calibration site and corresponding at-aperture spectral radiance values.		x		x
3.2.2.1.5	The IAS shall be able to calibrate the radiometric response of each ETM+ detector using Level 0R data from preship and prelaunch calibration sources and auxiliary calibration source data.				x
3.2.2.1.6	The IAS shall have the capability of assessing the short-term and long-term stability of the onboard calibration sources, which include the FASC, the PASC, and the internal calibrators.			x	
3.2.2.1.7	The IAS shall be able to integrate the results of the various calibration processes into an optimal estimate of radiometric calibration of each detector (except band 6) and provide new calibration parameters.		x		
3.2.2.1.8	The IAS shall be capable of generating radiometric calibration updates for the calibration parameter file.				x
3.2.2.1.9	The IAS shall be able to transfer the calibration of each detector to the internal calibrator.				x
3.2.2.2 Geometric Calibration					
3.2.2.2.1	The IAS shall be capable of determining the misalignment between the satellite navigational base reference and the ETM+ payload LOS.				x
3.2.2.2.2	The IAS shall be capable of determining band-to-band registration parameters.				x
3.2.2.2.3	The IAS shall be capable of characterizing and updating along and across scan parameters (i.e., scan mirror profiles, scan corrected mirror profile, detector offsets, detector delays).				x
3.2.2.2.4	The IAS shall be capable of generating geometric calibration updates for the calibration parameter file.				x
3.2.2.3 Level 1 Processing					
3.2.2.3.1	The IAS shall be capable of processing PCD data to correct spacecraft time, generate sensor pointing model (attitude and jitter), and calculate spacecraft position and velocity (ephemeris).				x
3.2.2.3.2	The IAS shall be capable of processing ETM+ Level 0R products to produce radiometrically corrected Level 1R image data.				x
3.2.2.3.3	The IAS shall be capable of creating systematically corrected ETM+ Level 1G imagery from Level 0R products.				x
3.2.2.3.4	The IAS shall be capable of creating precision corrected ETM+ Level 1G imagery from Level 0R products and GCPs.				x
3.2.2.3.5	The IAS shall be capable of creating terrain corrected ETM+ Level 1G imagery from Level 0R products, GCPs, and elevation data.				x

3.2.2.3.6	The IAS shall be capable of performing image-to-image registration.				x
3.2.2.3.7	The IAS shall be capable of incorporating IAS-generated calibration coefficient updates to generate Level 1 data.				x
3.2.2.3.8	The IAS shall support nearest neighbor, cubic convolution, and MTF compensation resampling.				x
3.2.2.3.9	The IAS shall have the capability to produce a 1G product with a grid cell size that is variable from 15 to 60 meters, in increments of 1 mm.				x
3.2.2.3.10	The IAS shall have the capability to map project 1G using the Space Oblique Mercator, Universal Transverse Mercator, Lambert Conformal Conic, Transverse Mercator, Oblique Mercator, and Polyconic coordinate reference systems.				x
3.2.2.3.11	The IAS shall have the capability to create a 1G image oriented to nominal path or north-up.				x
3.2.2.3.12	Deleted.				
3.2.2.3.12	The IAS shall be capable of processing MSCD to generate scan mirror and scan line corrector mirror models.				x
3.2.2.3.13	The IAS shall be capable of compensating for inoperable and saturated detectors during Level 1R and 1G processing.				x
3.2.2.3.14	The IAS shall be capable of compensating for the image artifacts of striping, banding, coherent noise, memory effect, and scan-correlated shift in Level 1R and 1G processing.				x
3.2.2.3.15	The IAS shall be capable of processing to Level 1R and 1G both ascending and descending pass ETM+ Level 0R data.				x
3.2.2.3.16	Deleted.				
3.2.2.4 Performance Evaluation					
3.2.2.4.1	The IAS shall evaluate the on-orbit operability of ETM+ detectors.		x		
3.2.2.4.2	The IAS shall be able to evaluate the absolute radiometric accuracy of ETM+ Level 0R, 1R, and 1G data.		x		
3.2.2.4.3	The IAS shall be able to assess the identified ETM+ radiometric image artifacts of striping; banding; random, correlated, and coherent noise; memory effect; and scan-correlated shift.				x
3.2.2.4.4	The IAS shall be able to evaluate the MTF of each ETM+ detector.		x		
3.2.2.4.5	The IAS shall be able to evaluate the SNR of each ETM+ detector, using prelaunch and on-orbit image data.		x		x
3.2.2.4.6	The IAS shall be capable of evaluating the on-orbit radiometric response of each ETM+ detector with respect to dynamic range.		x		
3.2.2.4.7	The IAS shall be capable of evaluating the on-orbit radiometric response of each ETM+ detector, excluding band 6, with respect to linearity (TBD).		x		
3.2.2.4.8	The IAS shall be able to evaluate the geodetic accuracy of ETM+ Level 1G image data.				x
3.2.2.4.9	The IAS shall be able to evaluate the internal geometric accuracy of ETM+ Level 1G image data.		x		
3.2.2.4.10	The IAS shall be able to evaluate the band-to-band registration accuracy of ETM+ imagery.				x

3.2.2.4.11	The IAS shall be able to evaluate the image-to-image registration accuracy of ETM+ data.				x
3.2.2.4.12	The IAS shall be able to evaluate the quality of Level 0R products. Quality checks will include but not be limited to those listed in Table 3.2.2.4-1.				x
3.2.2.4.13	The IAS shall be capable of performing a trend analysis over any desired time interval for each selected evaluation activity.			x	
3.2.2.4.14	Moved to 3.2.4.14.		x		x
3.2.2.4.15	The IAS shall provide the capability to visually inspect image data.			x	
3.2.2.4.16	The IAS shall provide a capability that allows an image analyst to monitor assessment processes and results.			x	
3.2.2.4.17	The IAS shall have the capability to review output data, including but not limited to calibration reports and updates.			x	
3.2.2.5 Incorporation of New Algorithms					
3.2.2.5.1	The IAS shall have the capability to acquire, develop, test, and add new algorithms and software to improve the radiometric and geometric properties of ETM+ data and their assessment without impacting IAS operations.		x	x	
3.2.2.5.2	The IAS shall support the development of algorithms to remove image artifacts and detector outages from Level 1R and 1G data without impacting normal IAS operations.			x	
3.2.2.5.3	The IAS shall have the capability to incorporate new algorithms into the operational system without impacting normal IAS operations.			x	
3.2.2.5.4	The IAS shall maintain configuration control of all algorithms, databases, software, and hardware used in operations.		x	x	
3.2.2.6 Processes Control and Manage Data					
3.2.2.6.1	The IAS shall be provide the capability to select the processing to be applied to data sets.				x
3.2.2.6.2	The IAS shall be capable of archiving all software and databases used in operations.		x	x	
3.2.2.6.3	The IAS shall be capable of storing selected data, parameters, ancillary data, reports, and documents.				x
3.2.2.6.4	The IAS shall have the ability to monitor and control processes.				x
3.2.2.6.5	The IAS shall be capable of storing selected GCPs and GCP chips.			x	
3.2.2.6.6	The IAS shall be capable of storing selected DEMs.			x	
3.2.2.6.7	Deleted.				
3.2.2.6.8	The IAS shall be capable of storing solar spectral and broadband radiance data.			x	
3.2.2.6.9	The IAS shall have the capability to write outputs to tape.				x
3.2.2.6.10	The IAS shall have the capability to generate hardcopy output.				x

3.2.2.6.11	The IAS shall archive selected prelaunch data, including but not limited to sensor engineering, ETM+ image data, alignment matrices, calibration measurements, mirror scan profiles, FASC BRDF, relative spectral subsystem response on a detector-by-detector basis, and required characterization data for performing in-flight calibrations.				x
3.2.2.6.12	The IAS shall allow the operator to select thresholds for results and errors reported by the IAS.				x
3.2.2.6.13	The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.				x
3.2.2.7 Reports and Summaries					
3.2.2.7.1	The IAS shall generate calibration, data quality assessment, and problem reports.				x
3.2.2.7.2	The IAS shall be capable of generating metadata for all reports sent to the EDC DAAC Guide server.				x
3.2.2.7.3	The IAS shall generate annual reports that document calibration coefficient and performance analysis trends.			x	
3.2.2.7.4	The IAS shall generate reports of anomaly detection analyses as they appear.			x	
3.2.2.7.5	The IAS shall generate processing summaries after each IAS activity.				x
3.2.3 Performance Requirements					
Accuracy					
3.2.3.1	The IAS shall be capable of calibrating the radiometric response (absolute spectral radiance) of each operable ETM+ detector to an accuracy of 5 percent, 1 sigma, providing all inputs are within specification.		x		x
3.2.3.2	The IAS shall be capable of calibrating the relative radiometric response such that the ratio of ETM+ equivalent at-aperture radiances between any combination of two spectral bands, excluding band 6, shall vary less than 2 percent, 1 sigma, over a 7-day period when exposed to a spectrally constant source.		x		x
3.2.3.3	The IAS shall contribute no greater than 0.7 percent uncertainty to absolute radiometric accuracy during the generation of Level 1R and 1G data.		x		x
3.2.3.4	The IAS shall be able to create systematic imagery to a geodetic accuracy of 250 meters, 1 sigma, providing all inputs are within specification. Performance applies to along-track and cross-track directions and is referenced to a nadir-viewing geometry.		x		x
3.2.3.5	The IAS shall contribute circular errors no greater than 1.8 meters, 1 sigma, in the production of systematically corrected ETM+ Level 1G imagery. This error is referenced to a nadir-viewing geometry and excludes the effect of terrain correction.		x		x
3.2.3.6	The IAS shall provide the capability to register pixels from a band to the corresponding pixels of the other bands in a common scene to an accuracy of 0.28 sensor GSD, 0.9p, in along-track and cross-track directions, providing all inputs are within specification. The accuracy is relative to the largest sensor GSD of the registered bands.		x		x

3.2.3.7	The IAS shall contribute error no greater than 0.11 multispectral sensor GSD, 0.9p, along-track, and 0.24 multispectral sensor GSD, 0.9p, cross-track in the assessment of band-to-band registration.				x
3.2.3.8	The IAS shall provide the capability to perform image-to-image registration to an accuracy of 0.4 multispectral sensor GSD, 0.9p, in the along-track and cross-track directions, providing all inputs are within specification.				x
3.2.3.9	The IAS shall contribute circular errors no greater than 3.6 meters, 1 sigma, during image-to-image registration correction of ETM+ Level 1G data. Error is referenced to a nadir-viewing geometry and excludes the effect of terrain correction.		x		x
3.2.3.10	The IAS shall be capable of estimating the field angles to an accuracy of 0.18 arcsec, 1 sigma.		x		x
3.2.3.11	The IAS shall be capable of digitally correlating common features in separate bands of the same image or same bands of separate images to an accuracy of 0.1 pixel, 0.9p.				x
3.2.3.12	The IAS shall be capable of estimating the alignment of the ETM+ line-of-sight to the satellite navigation base reference to an accuracy of 24 arcsec, 1 sigma, in all axes.		x		x
3.2.3.13	Deleted.				
Throughput					
3.2.3.14	The IAS shall be capable of generating the equivalent of up to 10 ETM+ Level 1G systematically corrected scenes in a 24-hour day over the life of the mission. (NOTE: This requirement is meant to size the maximum capacity of the system.)				x
3.2.3.15	The IAS shall be capable of receiving and storing 10 ETM+ Level 0R scene products or equivalent per day of data from the EDC DAAC.				x
3.2.3.16	The IAS shall be capable of archiving test site image data (initial, intermediate, and final products), characterization data, calibration data, calibration parameter files, and reports, generated by the IAS, over the life of the mission.		x	x	
3.2.3.17	The IAS shall generate monthly reports that document the quality of 0R data and 0R products retrieved from the EDC DAAC.				x
3.2.3.18	The IAS shall provide regular calibration and performance updates to the EDC DAAC and other interfaces quarterly.			x	
3.2.3.19	The IAS shall provide an annual Landsat 7 image quality report.				x
3.2.3.20	The IAS shall have an on-line data storage capacity of 100 GB (TBR) for image data.			x	
3.2.3.21	The IAS shall be capable of storing 68 MB of GCP data (points, chips, metadata).			x	
3.2.3.22	The IAS shall be capable of storing 20 GB of elevation data.			x	
3.2.4 Operational Requirements					
3.2.4.1	Deleted.				
3.2.4.2	The IAS shall support end-to-end testing before launch.			x	
3.2.4.3	The IAS shall be capable of supporting full operations at launch -6 months.			x	

3.2.4.4	The IAS shall support mission operations for a minimum of 5 years following IOC.		x		
3.2.4.5	The IAS shall operate two shifts for 7 days a week during IOC plus 48 days (TBR).	N/	A		
3.2.4.6	The IAS shall be staffed during prime shift post-IOC plus 48 days (TBR).	N/	A		
3.2.4.7	The IAS shall ensure backup of all on-line data and operations software.			x	
3.2.4.8	The IAS shall perform calibrations, assessments, and evaluations with frequencies specified in Tables 3.2.4-1 and 3.2.4-2.		x	x	
3.2.4.9	The IAS shall have the capability to maintain and upgrade all operational software.			x	
3.2.4.10	The IAS shall be capable of supporting training without impacting daily work loads.		x	x	
3.2.4.11	The IAS shall provide an operational availability of 0.85 (TBR) or better for all processing functions.		x		x
3.2.4.12	The IAS shall support an MTTR capability of 12 (TBR) hours or better.		x		x
3.2.4.13	The IAS shall be capable of retrieving cross-calibration data of other sensors from the EDC DAAC.				x
3.2.4.14	The IAS capability shall be used in performing anomaly, assessment, resolution, and reporting.		x		x

Section 5. Traceability

5.1 Requirements Traceability Matrix

Table 5-1 contains the Landsat 7 DMR-to-IAS-element specification traceability matrix.

Table 5-1. Landsat 7 DMR-to-IAS-Element Specification (1 of 3)

Landsat 7 DMR Req.	Landsat 7 DMR Requirements Summary	IAS Element Spec.
6400.01	The IAS shall perform the principal functions of receiving and processing data, performing calibrations, evaluating performance, and management.	3.2.1.1.1, 3.2.1.1.2, 3.2.2.4.16, 3.2.2.4.17, 3.2.2.6.9, 3.2.2.6.10, 3.2.2.7.1
6400.01.01	The IAS shall be capable of managing, scheduling, and controlling data and processing within the IAS.	3.2.1.2.1, 3.2.2.6.3, 3.2.2.6.4, 3.2.2.6.12, 3.2.2.6.13, 3.2.4.9
6400.01.02	The IAS shall be staffed to support system performance verification, interface testing, and end-to-end testing prior to launch.	3.2.4.2
6400.01.03	The IAS shall be capable of supporting full operations at launch -6 months.	3.2.4.3
6400.01.04	The IAS shall support mission operations for a minimum of 5 years following IOC.	3.2.4.4
6400.02	The IAS shall receive and process Landsat 7 data.	3.2.1.1.2, 3.2.2.3.1 - 3.2.2.3.5, 3.2.2.7.5
6400.02.01	The IAS shall receive Level 0R products and associated metadata from the EDC DAAC.	3.2.1.1.1
6400.02.02	The IAS shall process Level 0R data to produce radiometrically corrected Level 1R and radiometrically and geometrically corrected Level 1G images.	3.2.2.3.1 - 3.2.2.3.5, 3.2.2.3.7 - 3.2.2.3.11, 3.2.2.3.15, 3.2.2.3.16
6400.02.03	The IAS shall generate the equivalent of up to 10 ETM+ Level 1G systematically corrected scenes per day.	3.2.3.14, 3.2.3.15, 3.2.3.16
6400.02.04	The IAS shall create and maintain a library of geodetic control point data and digital elevation model data.	3.2.1.5.2, 3.2.2.6.5, 3.2.2.6.6, 3.2.3.21, 3.2.3.22
6400.02.05	The IAS shall remove image artifacts while processing Level 0R data to produce Level 1R images as required.	3.2.2.3.13, 3.2.2.3.14, 3.2.2.5.2
6400.02.06	The IAS shall produce products compatible with the standard specified in the Landsat 7 Program Coordinate Systems Standard.	3.2.2.3.10
6400.02.07	The IAS shall receive a definitive ephemeris, covering 7 days, once per week.	3.2.1.3.7

Table 5-1. Landsat 7 DMR-to-IAS-Element Specification (2 of 3)

Landsat 7 DMR Req.	Landsat 7 DMR Requirements Summary	IAS Element Spec.
6400.02.08	The IAS shall be capable of assessing on a sample basis the quality of ETM+ Level 0R products archived by the EDC DAAC.	3.2.2.4.1, 3.2.2.4.3 3.2.2.4.12, 3.2.2.4.15
6400.03	The IAS shall perform radiometric and geometric calibrations on selected Landsat 7 data.	3.2.2.1.1, 3.2.2.1.2, 3.2.2.1.3, 3.2.2.1.8, 3.2.2.2.1, 3.2.2.2.4, 3.2.3.12, 3.2.4.8
6400.03.01	The IAS shall calibrate the absolute radiometric response (abs. spectral rad.) of each operable ETM+ detector to the specified accuracy.	3.2.2.1.1, 3.2.2.1.2 3.2.2.1.3, 3.2.2.1.4 3.2.2.1.5, 3.2.3.1
6400.03.02	The IAS shall calibrate the relative radiometric response (rel. spectral rad.) of each operable ETM+ detector to the specified accuracy.	3.2.2.1.1, 3.2.2.1.2 3.2.2.1.3, 3.2.2.1.4 3.2.2.1.5
6400.03.03	The IAS shall determine and update calibration parameters.	3.2.2.1.7, 3.2.2.1.8 3.2.2.2.4
6400.03.04	The IAS shall determine the stability of the satellite's onboard calibration sources.	3.2.2.1.6
6400.03.05	The IAS shall determine misalignment between the satellite navigational base reference and the ETM+ line of sight.	3.2.2.2.1, 3.2.3.12
6400.03.06	The IAS shall determine the ETM+ field angle knowledge, determine scan mirror profiles, and assess band-to-band alignment.	3.2.2.2.2
6400.03.07	The IAS shall be capable of calibrating along and across scan parameters.	3.2.2.2.3 3.2.3.6
6400.04	The IAS shall evaluate the performance of the satellite, instrument, and ground processing procedures with respect to image radiometry and geometry and temporal registration.	3.2.2.3.6, 3.2.2.4.8 3.2.2.4.9, 3.2.2.4.10 3.2.2.4.11
6400.04.01	The IAS shall evaluate Landsat 7 system performance with respect to radiometric response and operability of each ETM+ detector, SNR, and system MTF for each spectral band.	3.2.2.4.1, 3.2.2.4.4 3.2.2.4.5, 3.2.2.4.6 3.2.2.4.7, 3.2.4.8
6400.04.02	The IAS shall determine the absolute radiometric accuracy of Level 1 ETM+ data and the geometric accuracy of Level 1G ETM+ data.	3.2.2.4.2, 3.2.2.4.8 3.2.2.4.9 - 3.2.2.4.11 3.2.3.1, 3.2.3.3-3.2.3.11
6400.04.03	The IAS shall assess the degree of streaking, banding, scan-line droop, coherent noise, correlated noise, and any artifacts discovered following launch.	3.2.2.4.3, 3.2.2.4.14
6400.04.04	The IAS shall monitor and perform long-term trend analyses of system performance and image quality.	3.2.2.4.13
6400.04.05	The IAS shall periodically compute sensor/satellite alignment, scan mirror profiles, and payload field angle knowledge and provide to the EDC DAAC.	3.2.2.2.1, 3.2.2.2.3, 3.2.2.2.4,

Table 5-1. Landsat 7 DMR-to-IAS-Element Specification (3 of 3)

Landsat 7 DMR Req.	Landsat 7 DMR Requirements Summary	IAS Element Spec.
6400.05	IAS shall manage the collection, dissemination, and storage of data related to IAS activities and ensure that the calibration and assessment procedures of the LSQAT are correctly executed.	3.2.2.6.2, 3.2.2.6.5 3.2.2.6.6, 3.2.2.6.8, 3.2.2.6.11
6400.05.01	The IAS shall send a calibration parameter file to the EDC DAAC.	3.2.1.1.3, 3.2.1.1.4 3.2.3.17, 3.2.3.18
6400.05.02	The IAS shall provide reprocessing requests and processing parameters to the LPS, as specified in the LPS-IAS ICD.	3.2.1.2.1, 3.2.1.2.2 3.2.1.2.4
6400.05.03	The IAS shall receive satellite and instrument performance data from the MOC and coordinate with the MOC for the acquisition of ETM+ image data required for image quality assessment.	3.2.1.3.1, 3.2.1.3.2 3.2.1.3.6
6400.05.04	The IAS shall send problem reports, calibration parameter file, ETM+ image requests, and ETM+ alignment data to the MOC.	3.2.1.3.3, 3.2.1.3.4 3.2.1.3.5, 3.2.2.7.1
6400.05.05	The IAS shall incorporate new algorithms as required to improve the radiometric and geometric properties of ETM+ data and their assessment.	3.2.2.5.1, 3.2.2.5.3 3.2.4.9
6400.05.06	The IAS shall maintain an archive of its product calibration data and correction parameters.	3.2.2.6.3, 3.2.2.6.11, 3.2.3.20
6400.05.07	The IAS shall produce data quality and system performance assessment reports.	3.2.2.7.1, 3.2.2.7.3 3.2.2.7.4, 3.2.3.17 3.2.3.19
6400.06	The IAS shall satisfy the performance requirements of the Landsat 7 system specification.	3.2.4.4

5.2 IAS Element Specifications to Landsat 7 DMR Traceability

3.2 REQS	IAS 3.2 ELEMENT SPECIFICATIONS SUMMARY	L7 DMR REQ
3.2.1 Interface Requirements (EDC DAAC, LPS, MOC, MMO)		
3.2.1.1.1	The IAS shall interface with the EDC DAAC for purposes of searching for and ordering of data from the Landsat 7 archive.	6400.01
3.2.1.1.2	The IAS shall receive Level 0R data and Level 0R products and associated ancillary data from the EDC DAAC.	6400.02 6400.02.01
3.2.1.1.3	The IAS shall interface with the EDC DAAC to coordinate the transfer of calibration parameter files and IAS-generated reports.	6400.05.01
3.2.1.1.4	The IAS shall send calibration parameter files, and IAS-generated reports to the EDC DAAC.	6400.05.01
3.2.1.2.1	The IAS shall interface with the LPS to coordinate the transfer of calibration parameter files and reprocessing requests.	6400.05.02
3.2.1.2.2	The IAS shall send reprocessing requests to the LPS.	6400.05.02
3.2.1.2.3	The IAS shall receive disposition of reprocessing requests from the LPS.	
3.2.1.2.4	The IAS shall send calibration parameter files to the LPS.	6400.05.02

3.2.1.3.1	The IAS shall send requests to the MOC for the operational acquisition of partial-aperture calibration data, full-aperture calibration data, and surface image data of radiometric and geometric calibration ground sites.	6400.05.03
3.2.1.3.2	The IAS shall coordinate with the MOC for the acquisition of ETM+ imagery required for calibration and image assessment, for the transfer of calibration parameter files, and for the transfer of problem reports.	6400.05.03
3.2.1.3.3	The IAS shall send requests to the MOC for concentrated definitive ephemeris.	
3.2.1.3.4	The IAS shall send problem reports to the MOC.	6400.05.04
3.2.1.3.5	The IAS shall send calibration parameter files to the MOC.	6400.05.04
3.2.1.3.6	The IAS shall be capable of receiving telemetry trend reports, spacecraft status reports, and event schedules from the MOC.	6400.05.03
3.2.1.3.7	The IAS shall be capable of receiving FDF-generated, definitive ephemeris from the MOC.	6400.02.07
3.2.1.4.1	The IAS shall send problem reports and summary reports to the MMO.	
3.2.2 Functional Requirements		
3.2.2.1 Radiometric Calibration		
3.2.2.1.1	The IAS shall be able to use data from the internal calibrator in the calibration of the radiometric response of each ETM+ detector.	6400.03 6400.03.01
3.2.2.1.2	The IAS shall be able to calibrate the radiometric response of each ETM+ detector, except band 6, using data from the PASC.	6400.03 6400.03.01
3.2.2.1.3	The IAS shall be able to calibrate the radiometric response of each ETM+ detector, except band 6, using data from the FASC.	6400.03.01
3.2.2.1.4	The IAS shall be able to calibrate the radiometric response of each ETM+ detector, given Level 0R data of a ground calibration site and corresponding at-aperture spectral radiance values.	6400.03.01
3.2.2.1.5	The IAS shall be able to calibrate the radiometric response of each ETM+ detector using Level 0R data from preship and prelaunch calibration sources and auxiliary calibration source data.	6400.03.01
3.2.2.1.6	The IAS shall have the capability of assessing the short-term and long-term stability of the onboard calibration sources, which include the FASC, the PASC, and the internal calibrators.	6400.03.04
3.2.2.1.7	The IAS shall be able to integrate the results of the various calibration processes into an optimal estimate of radiometric calibration of each detector (except band 6) and provide new calibration parameters.	6400.03.03
3.2.2.1.8	The IAS shall be capable of generating radiometric calibration updates for the calibration parameter file.	6400.03 6400.03.03
3.2.2.1.9	The IAS shall be able to transfer the calibration of each detector to the internal calibrator.	6400.03 6400.03.03
3.2.2.2 Geometric Calibration		

3.2.2.2.1	The IAS shall be capable of determining the misalignment between the satellite navigational base reference and the ETM+ payload LOS.	6400.03 6400.03.05
3.2.2.2.2	The IAS shall be capable of determining band-to-band registration parameters. (These are included in along/across scan parameters.)	6400.03.06
3.2.2.2.3	The IAS shall be capable of characterizing and updating along and across scan parameters (i.e., scan mirror profiles, scan corrected mirror profile, detector offsets, detector delays).	6400.03.07
3.2.2.2.4	The IAS shall be capable of generating geometric calibration updates for the calibration parameter file.	6400.03
3.2.2.3 Level 1 Processing		
3.2.2.3.1	The IAS shall be capable of processing PCD data to correct spacecraft time, generate sensor pointing model (attitude and jitter), and calculate spacecraft position and velocity (ephemeris).	6400.02 6400.02.02
3.2.2.3.2	The IAS shall be capable of processing ETM+ Level 0R products to produce radiometrically corrected Level 1R image data.	6400.02 6400.02.02
3.2.2.3.3	The IAS shall be capable of creating systematically corrected ETM+ Level 1G imagery from Level 0R products.	6400.02 6400.02.02
3.2.2.3.4	The IAS shall be capable of creating precision corrected ETM+ Level 1G imagery from Level 0R products and GCPs.	6400.02 6400.02.02
3.2.2.3.5	The IAS shall be capable of creating terrain corrected ETM+ Level 1G imagery from Level 0R products, GCPs, and elevation data.	6400.02 6400.02.02
3.2.2.3.6	The IAS shall be capable of performing image-to-image registration.	6400.04
3.2.2.3.7	The IAS shall be capable of incorporating IAS-generated calibration coefficient updates to generate Level 1 data.	6400.02.02
3.2.2.3.8	The IAS shall support nearest neighbor, cubic convolution, and MTF compensation resampling.	6400.02.02
3.2.2.3.9	The IAS shall have the capability to produce a 1G product with a grid cell size that is variable from 15 to 60 meters, in increments of 1 mm.	6400.02.02
3.2.2.3.10	The IAS shall have the capability to map project 1G using the Space Oblique Mercator, Universal Transverse Mercator, Lambert Conformal Conic, Transverse Mercator, Oblique Mercator, and Polyconic coordinate reference systems.	6400.02.02 6400.02.06
3.2.2.3.11	The IAS shall have the capability to create a 1G image oriented to nominal path or north-up.	6400.02.02
3.2.2.3.12	Deleted.	
3.2.2.3.12	The IAS shall be capable of processing MSCD to generate scan mirror and scan line corrector mirror models.	6400.03.06 6400.04.05
3.2.2.3.13	The IAS shall be capable of compensating for inoperable and saturated detectors during Level 1R and 1G processing.	6400.02.05
3.2.2.3.14	The IAS shall be capable of compensating for the image artifacts of, striping, banding, coherent noise, memory effect, and scan correlated shift in Level 1R and 1G processing.	6400.02.05
3.2.2.3.15	The IAS shall be capable of processing to Level 1R and 1G both ascending and descending pass ETM+ Level 0R data.	6400.02.02
3.2.2.3.16	Deleted.	6400.02.02

3.2.2.4 Performance Evaluation		
3.2.2.4.1	The IAS shall evaluate the on-orbit operability of ETM+ detectors.	6400.04.01
3.2.2.4.2	The IAS shall be able to evaluate the absolute radiometric accuracy of ETM+ Level 0R, 1R, and 1G data.	6400.04.02
3.2.2.4.3	The IAS shall be able to assess the identified ETM+ radiometric image artifacts of striping; banding; random, correlated, and coherent noise; memory effect; and scan correlated shift.	6400.02.05
3.2.2.4.4	The IAS shall be able to evaluate the MTF of each ETM+ detector.	6400.04.01
3.2.2.4.5	The IAS shall be able to evaluate the SNR of each ETM+ detector, using prelaunch and on-orbit image data.	6400.04.01
3.2.2.4.6	The IAS shall be capable of evaluating the on-orbit radiometric response of each ETM+ detector with respect to dynamic range.	6400.04.01
3.2.2.4.7	The IAS shall be capable of evaluating the on-orbit radiometric response of each ETM+ detector, excluding band 6, with respect to linearity (TBD).	6400.04.01
3.2.2.4.8	The IAS shall be able to evaluate the geodetic accuracy of ETM+ Level 1G image data.	6400.04 6400.04.02
3.2.2.4.9	The IAS shall be able to evaluate the internal geometric accuracy of ETM+ Level 1G image data.	6400.04 6400.04.02
3.2.2.4.10	The IAS shall be able to evaluate the band-to-band registration accuracy of ETM+ imagery.	6400.04 6400.04.02
3.2.2.4.11	The IAS shall be able to evaluate the image-to-image registration accuracy of ETM+ data.	6400.04 6400.04.02
3.2.2.4.12	The IAS shall be able to evaluate the quality of Level 0R products. Quality checks will include but not be limited to those listed in Table 3.2.2.4-1.	6400.02.08
3.2.2.4.13	The IAS shall be capable of performing a trend analysis over any desired time interval for each selected evaluation activity.	6400.04.04
3.2.2.4.14	Moved to 3.2.4.14.	
3.2.2.4.15	The IAS shall provide the capability to visually inspect image data.	6400.02.08
3.2.2.4.16	The IAS shall provide a capability that allows an image analyst to monitor assessment processes and results.	6400.01
3.2.2.4.17	The IAS shall have the capability to review output data, including but not limited to calibration reports and updates.	6400.01
3.2.2.5 Incorporation of New Algorithms		
3.2.2.5.1	The IAS shall have the capability to acquire, develop, test, and add new algorithms and software to improve the radiometric and geometric properties of ETM+ data and their assessment without impacting IAS operations.	6400.05.05
3.2.2.5.2	The IAS shall support the development of algorithms to remove image artifacts and detector outages from Level 1R and 1G data without impacting normal IAS operations.	6400.02.05
3.2.2.5.3	The IAS shall have the capability to incorporate new algorithms into the operational system without impacting normal IAS operations.	6400.05.05

3.2.2.5.4	The IAS shall maintain configuration control of all algorithms, databases, software, and hardware used in operations.	6400.01
3.2.2.6 Control Processes and Manage Data		
3.2.2.6.1	The IAS shall provide the capability to select the processing to be applied to data sets.	6400.01.01
3.2.2.6.2	The IAS shall be capable of archiving all software and databases used in operations	6400.01.01 6400.05
3.2.2.6.3	The IAS shall be capable of storing selected data, parameters, ancillary data, reports, and documents.	6400.05.06
3.2.2.6.4	The IAS shall have the ability to monitor and control processes.	6400.01.01
3.2.2.6.5	The IAS shall be capable of storing selected GCPs and GCP chips.	6400.02.04
3.2.2.6.6	The IAS shall be capable of storing selected DEMs.	6400.02.04
3.2.2.6.7	Deleted.	
3.2.2.6.8	The IAS shall be capable of storing solar spectral and broadband radiance data.	6400.03
3.2.2.6.9	The IAS shall have the capability to write outputs to tape.	6400.05
3.2.2.6.10	The IAS shall have the capability to generate hardcopy outputs.	6400.05
3.2.2.6.11	The IAS shall archive selected prelaunch data, including but not limited to sensor engineering, ETM+ image data, alignment matrices, calibration measurements, mirror scan profiles, FASC BRDF, relative spectral subsystem response on a detector-by-detector basis, and required characterization data for performing in-flight calibrations.	6400.05 6400.05.06
3.2.2.6.12	The IAS shall allow the operator to select thresholds for results and errors reported by the IAS.	6400.01.01
3.2.2.6.13	The IAS shall automatically generate messages and alarms to alert the operator to IAS results and errors that exceed selected thresholds.	6400.01.01
3.2.2.7 Report and Summaries		
3.2.2.7.1	The IAS shall generate calibration, data quality assessment, and problem reports.	6400.05.07
3.2.2.7.2	The IAS shall be capable of generating metadata for all reports sent to the EDC DAAC.	6400.05.01
3.2.2.7.3	The IAS shall generate annual reports that document calibration coefficient and performance analysis trends.	6400.05.07
3.2.2.7.4	The IAS shall generate reports of anomaly detection analyses as they appear.	6400.05.07
3.2.2.7.5	The IAS shall generate processing summaries after each IAS activity.	6400.02
3.2.3 Performance Requirements		
<u>Accuracy</u>		
3.2.3.1	The IAS shall be capable of calibrating the radiometric response (absolute spectral radiance) of each operable ETM+ detector to an accuracy of 5 percent, 1 sigma, providing all inputs are within specification.	6400.03.01 6400.04.02

3.2.3.2	The IAS shall be capable of calibrating the relative radiometric response such that the ratio of ETM+ equivalent at-aperture radiances between any combination of two spectral bands, excluding band 6, shall vary less than 2 percent, 1 sigma, over a 7-day period when exposed to a spectrally constant source.	6400.03.02
3.2.3.3	The IAS shall contribute no greater than 0.7 percent uncertainty to absolute radiometric accuracy during the generation of Level 1R and 1G data.	6400.04.02
3.2.3.4	The IAS shall be able to create systematic imagery to a geodetic accuracy of 250 meters, 1 sigma, providing all inputs are within specification. Performance applies to along-track and cross-track directions and is referenced to a nadir-viewing geometry.	6400.04.02
3.2.3.5	The IAS shall contribute circular errors no greater than 1.8 meters, 1 sigma, in the production of systematically corrected ETM+ Level 1G imagery. This error is referenced to a nadir-viewing geometry and excludes the effect of terrain correction.	6400.04.02
3.2.3.6	The IAS shall provide the capability to register pixels from a band to the corresponding pixels of the other bands in a common scene to an accuracy of 0.28 sensor GSD, 0.9p, in along-track and cross-track directions, providing all inputs are within specification. The accuracy is relative to the largest sensor GSD of the registered bands.	6400.03.07 6400.04.02
3.2.3.7	The IAS shall contribute error no greater than .11 multispectral sensor GSD, 0.9p, along-track, and 0.24 multispectral sensor GSD, 0.9p, cross-track, in the assessment of band-to-band registration.	6400.04.02
3.2.3.8	The IAS shall provide the capability to perform image-to-image registration to an accuracy of 0.4 multispectral sensor GSD, 0.9p, in the along-track and cross-track directions, providing all inputs are within specification.	6400.04.02
3.2.3.9	The IAS shall contribute circular errors no greater than 3.6 meters, 1 sigma, during image-to-image registration correction of ETM+ Level 1G data. Error is referenced to a nadir-viewing geometry and excludes the effect of terrain correction.	6400.04.02
3.2.3.10	The IAS shall be capable of estimating the field angles to an accuracy of 0.18 arcsec, 1 sigma.	6400.04.02
3.2.3.11	The IAS shall be capable of digitally correlating common features in separate bands of the same image or same bands of separate images to an accuracy of 0.1 pixel, 0.9p.	6400.04.02
3.2.3.12	The IAS shall be capable of estimating the alignment of the ETM+ line-of-sight to the satellite navigation base reference to an accuracy of 24 arcsec, 1 sigma, in all axes.	6400.03 6400.03.05
Throughput		
3.2.3.14	The IAS shall be capable of generating the equivalent of up to 10 ETM+ Level 1G systematically corrected scenes in a 24-hour day over the life of the mission.	6400.02.03
3.2.3.15	The IAS shall be capable of receiving and storing 10 ETM+ Level 0R scene products or equivalent per day of data from the EDC DAAC.	6400.02.03

3.2.3.16	The IAS shall be capable of archiving test site image data (initial, intermediate, and final products), characterization data, calibration data, calibration parameter files, and reports, generated by the IAS, over the life of the mission.	6400.02.03
3.2.3.17	The IAS shall generate monthly reports that document the quality of OR data and OR products retrieved from the EDC DAAC.	6400.05.01 6400.05.07
3.2.3.18	The IAS shall provide regular calibration and performance updates to the EDC DAAC and other interfaces quarterly.	6400.05.01
3.2.3.19	The IAS shall provide an annual Landsat 7 image quality report.	6400.05.07
3.2.3.20	The IAS shall have an on-line data storage capacity of 100 GB (TBR) for image data.	6400.05.06
3.2.3.21	The IAS shall be capable of storing 68 MB of GCP data (points, chips, metadata).	6400.02.04
3.2.3.22	The IAS shall be capable of storing 20 GB of elevation data.	6400.02.04
3.2.4 Operational Requirements		
3.2.4.1	Deleted.	
3.2.4.2	The IAS shall support end-to-end testing before launch.	6400.01.02
3.2.4.3	The IAS shall be capable of supporting full operations at launch -6 months.	6400.01.03
3.2.4.4	The IAS shall support mission operations for a minimum of 5 years following IOC.	6400.01.04
3.2.4.5	The IAS shall operate two shifts for 7 days a week during IOC plus 48 days (TBR).	6400.01
3.2.4.6	The IAS shall be staffed during prime shift post-IOC plus 48 days (TBR).	6400.01
3.2.4.7	The IAS shall ensure backup of all on-line data and operations software.	6400.01.01
3.2.4.8	The IAS shall perform calibrations, assessments, and evaluations with frequencies specified in Tables 3.2.4-1 and 3.2.4-2.	6400.03 6400.04.01
3.2.4.9	The IAS shall have the capability to maintain and upgrade all operational software.	6400.01.01, 6400.05.05
3.2.4.10	The IAS shall be capable of supporting training without impacting daily work loads.	
3.2.4.11	The IAS shall provide an operational availability of 0.85 (TBR) or better for all processing functions.	6400.01.04
3.2.4.12	The IAS shall support an MTTR capability of 12 (TBR) hours or better.	6400.01.04
3.2.4.13	The IAS shall be capable of receiving and storing cross-calibration data from other sensors.	6400.05
3.2.4.14	The IAS capability shall be used in performing anomaly assessment, resolution, and reporting.	6400.04.03

Section 6. Notes

6.1 Glossary

0R: The stage in the processing before radiometric or geometric correction of an image and after the pixels have been placed in detector spatial order.

0R product: Products distributed by the EDC DAAC, to include all bands; 0R image data, metadata, radiometric calibration data, calibration parameter file, payload correction data (PCD), and MSCD.

1R: The stage in the processing after radiometric correction has been applied to an image.

1G: The final stage in the processing after radiometric and geometric corrections have been applied to the image data.

Ancillary data: Spacecraft attitude and ephemeris, radiometric correction coefficients, geometric processing parameters, and image quality statistics.

Archive: Off-line storage of data, software, and documentation.

ASPAM: A model that creates a report on meteorological conditions, including such items as pressure, temperature, and water vapor content as a function of altitude, at a particular time and place, derived from empirical and interpolated data by USAFETAC (more than 48 hours after the fact).

Bright Target Recovery: Also known as memory effect.

Calibration activities: Recalculating of the radiometric correction coefficients or geometric processing parameters.

Data storage: On-line storage of data accessible to the various functions within the IAS.

Dead detectors: Nonresponsive detectors.

Degraded detectors: Also known as inoperable detectors (see definition).

Equivalent at-aperture radiance: Estimated radiance from other than full-aperture radiance.

Entrance aperture radiance: Actual full-aperture radiance.

ETM+ Equivalent Scene:

L0R image data $(6320+225) \times 5984 \times 6 + ((12640+450) \times 11968) + ((3160+113) \times 2992 \times 2) =$
0.41 GB

Level 1G, nonrotated, resampled to 25m (except Pan to 12.5m)
 $220\text{km} \times 170\text{km} / (.025\text{km/pix})^2 \times 2 \text{ bytes/pix} \times 7 \text{ bands} +$
 $220\text{km} \times 170\text{km} / (.0125\text{km/pix})^2 \times 2 \text{ bytes/pix} = 1.3 \text{ GB}$

Geodetic accuracy: The accuracy relative to the geodetic reference surface, the Earth ellipsoid.

Geometric accuracy: The measure of internal distortion of an image.

Geometric artifacts: Assessment of geometric artifacts (or assessment of geometric accuracy) includes visual assessment of discontinuities of linear features, scale distortion, panoramic distortion, and any other distortions.

Geometric processing parameters: Orbit parameters, instrument and alignment parameters, focal plane band locations, scan mirror profile coefficients (along scan and across scan), odd detector sample shifts, alignment matrixes, Angular Displacement Sensor (ADS) calibration parameters, gyro calibration parameters, along scan focal plane detector offsets, temperature calibration coefficients, inoperable modes, resampling coefficients, MTF coefficients, and MTF compensation.

Ground look calibration: The process of radiometrically calibrating the payload, on-orbit, by comparing payload readings to estimated radiances reaching the payload from ground scenes using onsite ground and atmospheric measurements.

Ground measurement data: Also known as ground truth data.

- Normal image data of ground truth site collected in low gain mode
- In-band target radiance measurements coincident with the Landsat 7 overpass
- In-band irradiance measurements of the ground
- Temperatures of the water at selected depths from the surface to 1 meter below the surface (for band 6 calibration)
- Air temperature and wind speed and direction just above the water temperature probes (for band 6 calibration)
- Atmospheric measurements, to include
 - Pressure, temperature, and relative humidity/water vapor density as a function of altitude as reported by radiosondes launched within 1 hour before the overpass of Landsat 7
 - Surface-level pressure, temperature, and relative humidity/water vapor density
 - Surface-level aerosol measurements and a ground visibility measurement within one-half hour of the overpass
 - Lidar measurements of water vapor density as a function of altitude within 5 minutes of the overpass
- Full ASPAM report from USAFETAC for comparison

In-orbit checkout (IOC): The 45-day period specified after launch during which spacecraft and sensor systems are activated, checked out, outgassed, and initially calibrated.

Initial operational capability: Milestone after satellite initialization and checkout wherein operations are transferred from the developers (NASA) to the system operators (NOAA).

Inoperable detectors: Detectors meeting the following criteria shall be declared inoperable:

- The quantized digital number (DN) is below 50 percent of the full-scale DN value when a detector is exposed to the ETM+ minimum saturation levels.
- The quantized DN reaches full scale while the input radiance is at or below 0.70 times the ETM+ minimum saturation levels.
- The SNR performance degrades to 50 percent or below the specified ETM+ minimum SNR values.

Level 0R scene product: See *0R product*.

Level 1G data: Includes both 1G imagery and geometric correction data.

Level 1G imagery: Image data that have been geometrically corrected.

Payload correction data (PCD): The PCD contain all data required by ground stations to geometrically correct ETM+ sensor data and redundantly provide the ETM+ imaging configuration. The PCD are embedded in every wideband data virtual channel data unit (VCDU) at a rate of 4 bytes of PCD per VCDU. PCD data items are

- ADS
- ADS temperature
- Gyro data
- Gyro drift data
- Attitude estimate
- Time of last SV clock update
- SV time drift characterization data
- Ephemeris
- ETM+ telemetry data
- Spacecraft ID and time code
- Multiplexer status
- PDF A/D ground reference
- Minor frame sync
- Major frame identification
- Spacecraft identifier
- Attitude control system mode
- ETM+ on/off times

Radiometric processing parameters: Includes the radiometry parameters in the calibration parameter file (prelaunch gains, initial postlaunch gains, most current gains, detector status table, offset window locations, nominal biases, and scale factors) plus IAS-maintained calibration parameters from individual calibration sources and the combined radiometric model (CRAM).

Radiometric image artifacts: Striping, banding, scan correlated shift, bright target recovery response (aka memory effect), coherent noise, impulse noise, detector saturation, and detector inoperability.

Test sites: Geometric test sites include five primary sites:

- Iowa (Path 28, Row 30)
- EROS (Path 29, Row 29)
- Texas (Path 28, Row 37)
- Northern Minnesota (Path 28, Row 27)
- Colorado Springs (Path 33, Row 33)

Test sites include 3 secondary sites:

- Iowa II (Path 27, Row 30)
- Iowa III (Path 26, Row 30)
- Wichita (Path 28, Row 34)

Radiometric test sites include

- White Sands Alkali Flats, NM (33N, 106W)
- Rogers Dry Lake Bed, CA (35N, 118W)
- Lake Tahoe, CA (40N, 120W)

6.2 Acronyms

ACCA	Automated Cloud Cover Assessment
ADS	Angular Displacement Sensor
BRDF	Bi-directional Reflectance Distribution Function
CRAM	combined radiometric model
DEM	digital elevation model
DMR	detailed mission requirements
DN	digital number
EDC	EROS Data Center
EDC DAAC	EROS Data Center Distributed Active Archive Center

EROS	Earth Resources Observation System
ETM+	Enhanced Thematic Mapper Plus
FASC	full-aperture solar calibrator
FDF	Flight Dynamics Facility
FHSERR	First Half Scan Error
GB	gigabyte
GCP	ground control point
GSD	guide star data
GSFC	Goddard Space Flight Center
IAS	Image Assessment System
IGS	International Ground Station
IOC	In-orbit checkout
LMMS	Lockheed Martin Marietta Space
LOS	line-of-sight
LPS	Landsat 7 Processing System
LSQAT	Landsat Quality Assurance Team
MB	megabyte
mm	millimeter
MMO	Mission Management Office
MOC	Mission Operations Center
MSCD	Mirror Scan Correction Data
MTF	Modulation Transfer Function
MTTR	mean time to restore
NASA	National Aeronautics and Space Administration
PASC	partial-aperture solar calibrator
PCD	Payload Correction Data
SBRC	Santa Barbara Research Center; Division, Hughes Aircraft
SHSERR	Second Half Scan Error
SNR	signal-to-noise ratio
VCDU	virtual channel data unit
WRS	Worldwide Reference System